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(19)

(54) IMPROVEMENTS IN OR RELATING TO ROTARY ELECTROMAGNETIC DEVICES

(71) We, ELLIOTT BROTHERS (LONDON) LIMITED of Marconi House, New Street, Chelmsford, Essex, CM1 1PL, formerly of Century Works, Lewisham, London, S.E.13, a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to rotary electromagnetic devices of the type known as synchros as are employed, for example, for translating a mechanical position or motion into electrical information or vice versa, such devices comprising essentially a wound rotor and stator, the latter having windings so arranged that, when the rotor winding is supplied with alternating current, they can be used to provide an output which is dependent upon the angular position of the rotor with respect to the stator, or alternatively can be used for feeding into the device an input which determines the angular position of the rotor.

Such devices as originally constructed commonly made use of brushes and slip rings for supplying current to the rotor winding; however the resultant friction was, for some applications at least, found to be detrimental to the satisfactory operation of the devices, and consequently a number of synchros have been proposed in which the need for brushes and slip rings avoided. Thus in one form of such a brushless synchro, as they are generally known, the rotor and stator carry additional inductively coupled windings which act, in effect, as a transformer, the additional rotor winding being connected to the main synchro rotor winding, and the additional stator winding being provided with terminals for connection to an alternating current supply.

The core structure of the transformer in such brushless synchros comprises two concentric sections of a ferromagnetic metal, such as steel, suitable for carrying the magnetic flux, fixed to the main synchro housing and to the rotor shaft respectively, the stationary and rotating sections being separated by a small annular air gap; hitherto the core sections have been constructed as solid metal elements for ease of manufacture and in view of the small dimensional tolerances allowable.

According to the present invention in a brushless synchro incorporating a transformer comprising a stator section and a rotor section for supplying current to the synchro rotor winding, the two sections of the transformer being concentric, a core section of the transformer comprises a plurality of axially and radially extending laminations, supported in angularly spaced relationship by an electrically insulating bonding agent, for example a thermosetting synthetic resin.

In such a brushless synchro the transformer is found to give a better electrical performance, particularly as regards iron losses, phase shift of output voltage, and no load current, and can readily be constructed using laminations stamped and annealed in accordance with known techniques, the laminations being assembled in a jig and secured together by said bonding agent in a suitably shaped mould to form a solid unit, which can subsequently be machined, if necessary, to correct dimensional limits.

The invention also provides a method of manufacturing a core section of the transformer of a brushless synchro according to the invention including the steps of supporting the laminations in a mould with the said angularly spaced relationship, and introducing a thermosetting epoxy resin into the mould and curing the resin to

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secure the laminations together and form a rigid structure.

Any convenient means may be provided for supporting the laminations in the mould prior to the introduction of the bonding agent. For example the wall of the mould or a separate jig within the mould may be provided with locating recesses which accommodate parts of the laminations so as to support the laminations with the said angularly spaced relationship. The parts of the laminations which fit into the locating recesses may in some cases be provided by lugs on the laminations which can be removed from the completed structure, for example by machining, following its removal from the mould.

In a brushless synchro according to the invention the rotor section of the transformer conveniently includes a core section comprising a plurality of U-shaped laminations disposed in angularly spaced relationship around the rotor shaft with the limbs of the U extending radially outwards. The base portion of each U-shaped lamination is conveniently in the form of a straight strip with the two limbs projecting from the ends of the strip at right angles thereto and in the plane of the strip. Thus in its assembled form such a core section will consist essentially of a hollow cylindrical stem formed by the base portions of the laminations and designed for mounting on the rotor shaft, and having at each end an outwardly directed circular flange formed by the radially extending limbs. The transformer rotor winding will then be wound around the stem between the two end flanges, the flux path being complete through the structure, whilst the laminated construction will significantly reduce the iron losses compared with those produced in the solid core sections previously employed.

In a brushless synchro according to the invention the stator section of the transformer may include a core section comprising a plurality of L-shaped laminations arranged with one limb directed radially inwards and the other limb extending in an axial direction, the laminations being supported in the said angularly spaced relationship by the bonding agent to form a hollow cylindrical shell with an inwardly directed flange at one end. The transformer stator winding is located within the shell and the assembly is completed by the attachment of a ferromagnetic disc to the open end of the structure so as to complete the flux path. This disc may be solid or have a laminated construction.

Alternatively, in a brushless synchro in accordance with the invention the stator section of the transformer may include a core section comprising a plurality of U-shaped laminations secured together by said bonding agent in said angularly spaced relationship with the limbs of the U directed radially inwards, and the bases of the laminations providing a hollow cylindrical shell, the stator winding being located within the shell.

With such an arrangement the stator winding is pre-wound, the U-shaped laminations being assembled around the coil with the limbs of the U directed radially inwards, and then secured to each other and to the winding by the bonding agent, so that the winding and laminations form a complete moulded assembly. Such a construction avoids the need for a separate end disc and makes the stator assembly a more solid construction.

It may in some cases be found that a cogging effect is produced at the air-gap surfaces between the rotor and stator core sections due to the ends of the laminations. This disadvantage can be substantially avoided by providing a ring of ferromagnetic material having a smooth surface around the periphery of each of the two flanges at the ends of the rotor core section. A similar ring may be secured within the opening in the or each flange formed by the inwardly directed laminations of the stator core.

The invention is applicable to brushless synchros of all types, for example control synchros, torque synchros and resolvers.

One brushless synchros employing a transformer utilising core sections constructed in accordance with the invention, together with its method of manufacture, and two modifications thereof, will now be described by way of example with reference to Figures 1 to 3 of the accompanying drawing, in which Figure 1 represents an exploded view in part section of the synchro, showing the construction of the transformer, and Figures 2 and 3 show parts of modified core sections.

The synchro illustrated in Figure 1 comprises essentially a rotor 1 and a stator 2 each having a main winding 3, 4, respectively, these being of any suitable known form, and the rotor shaft 5 being journalled in bearings 6 which are held in bearing housings 7 at the ends of the stator casing 8 by C-springs 9. Leads 10 to the main stator winding 4 are provided for enabling an input to be fed into the synchro or an output to be taken therefrom, depending upon its particular function.

In order to enable an alternating current to be supplied to the main rotor winding in use of the device there are provided further rotor and stator windings 11, 12 each associated with a core section 13, 14 respectively and together providing a concentric transformer. The stator section of

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the transformer is mounted within the casing 8, input leads 15 being provided for supplying an alternating current input to the transformer stator winding which constitutes the primary of the transformer. The rotor section of the transformer is mounted on the rotor shaft, the transformer rotor winding constituting the transformer secondary and being connected to the main synchro rotor winding 3 by leads 16.

In accordance with the invention the rotor core section 13 is formed from a number of U-shaped laminations 18 uniformly spaced around the rotor axis with the limbs 19 of the U extending radially outwards, the laminations being held together in their angularly spaced relationship by a suitable bonding agent to form a rigid structure. The base 20 of each U-shaped lamination is in the form of a straight strip with the two limbs extending at right angles to the length of the strip so that the assembled structure comprises a hollow central stem having an outwardly directed flange 25, provided by the limbs of the laminations, at each end, the transformer rotor winding 11 being wound around the central stem between the two end flanges as shown.

In the manufacture of the rotor core section the individual laminations, which can be stamped from a steel sheet and annealed in known manner, are assembled in a jig in an appropriately shaped mould and supported thereby with a uniform angular spacing. A thermosetting epoxy resin or other suitable bonding agent is then introduced into the mould and cured to secure the laminations together and form a rigid structure.

The stator core section 14 is formed from a number of L-shaped laminations 21 each arranged with the shorter limb 22 directed radially inwards and the longer limb 23 extending in an axial direction. the laminations being bonded together by an epoxy resin or other suitable bonding agent to form a solid structure as in the case of the rotor section. In this case however the structure is in the form of a hollow shell having an annular flange provided by the shorter limbs of the laminations extending inwards at one end, the other end of the structure being open. The transformer stator winding 12 is located within the shell, and the core section is completed by the addition of a ferromagnetic disc 24 to the open end of the structure as shown, the whole assembly being secured in position within the stator casing 8 in any suitable manner.

In a modified construction illustrated in part in Figure 2 the stator core section 14 is formed from a number of U-shaped laminations 31 having the limbs of the U directed radially inwards. The stator section can be constructed by pre-winding the stator winding 12 and then assembling the U-shaped laminations around the winding with a uniform angular spacing, and then moulding them in place with an epoxy resin or other suitable bonding agent so that the laminations and the winding form a rigid assembly.

In some cases it may be found that ends of the laminations produce a cogging effect at the air-gap surfaces between the rotor and stator cores. This is substantially avoided by the modified construction illustrated in part in Figure 3. In this modification the periphery of each of the two flanges 25 at the ends of the rotor core section is surrounded by a smooth relatively thin ring 32 of ferromagnetic material. A similar ring is preferably then also provided within the opening at the centre of the or each flange which is formed by the inwardly extending limbs of the stator core laminations in the arrangement illustrated in Figure 1 or Figure 2, for example as indicated by the broken lines 33 of Figure 2.

In the manufacture of rotor or stator core sections employing such rings the ring or rings are conveniently supported in the required position relative to the laminations within the mould and secured to the laminations by the thermosetting epoxy resin.

In the assembled synchro the core sections provide the magnetic circuit of the transformer, the end portions of the rotor and stator sections being separated by a small air gap only, the remainder of the circuit being completed through the laminations. The rigid core structures formed in accordance with the invention can be machined, if necessary, to highly accurate dimensions as in the case of solid metal sections employed hitherto, but because of their laminated structure the iron losses are reduced and the electrical performance of the transformer is improved.

WHAT WE CLAIM IS:—

1. A brushless synchro incorporating a transformer comprising a stator section and a rotor section for supplying current to the synchro rotor winding, the two sections of the transformer being concentric, wherein a core section of the transformer comprises a plurality of axially and radially extending laminations, supported in angularly spaced relationship by an electrically insulating bonding agent.

2. A brushless synchro according to Claim 1 wherein the electrically insulating

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bonding agent consists of a thermosetting synthetic resin.

3. A brushless synchro according to Claim 1 or 2 wherein the rotor section of the transformer includes a core section comprising a plurality of U-shaped laminations secured together by said bonding agent in angularly spaced relationship around the rotor shaft, with the limbs of the U extending radially outwards; the transformer rotor winding surrounding the stem of the assembly provided by the bases of the laminations.

4. A brushless synchro according to Claim 3 wherein the periphery of each of the two flanges formed at the ends of the core section by the outwardly directed limbs of the laminations is surrounded by a ferromagnetic ring secured to the respective flange by the bonding agent.

5. A brushless synchro according to Claim 1 or 2 wherein the stator section of the transformer includes a core section comprising a plurality of L-shaped laminations arranged with one limb directed radially inwards and the other limb extending in an axial direction, the laminations being supported in the said angularly spaced relationship by the bonding agent to form a hollow cylindrical shell with an inwardly directed flange at one end; and a disc of ferromagnetic material secured to the opposite end of the shell, the transformer stator winding being located within the shell between the flange and the disc.

6. A brushless synchro according to Claim 5 wherein the disc has a laminated construction.

7. A brushless synchro according to Claim 1 or 2 wherein the stator section of the transformer includes a core section comprising a plurality of U-shaped laminations secured together by said bonding agent in said angularly spaced relationship with the limbs of the U directed radially inwards, so that the bases of the laminations provide a hollow cylindrical shell, the transformer stator winding being located within the shell.

8. A brushless synchro according to Claim 5 or 7 wherein a ferromagnetic ring is secured within the opening in the or each flange formed by the inwardly directed limbs of the core laminations.

9. A method of forming the rotor section of the transformer of a brushless synchro according to Claim 3 including the steps of assembling the laminations in a mould and supporting them therein with the said angularly spaced relationship, and introducing a thermosetting epoxy resin into the mould and curing the resin to secure the laminations together and form a rigid structure, the transformer rotor winding being subsequently wound around the stem of the structure.

10. A method of forming the stator section of the transformer of a brushless synchro according to Claim 5 or 6, including the steps of assembling the laminations in a mould and supporting them therein with the said angularly spaced relationship, introducing a thermosetting epoxy resin into the mould and curing the resin to secure the laminations together and form a rigid structure, introducing the transformer stator winding into the hollow shell so formed, and attaching a ferromagnetic disc to the end of the shell to complete the structure.

11. A method of forming the stator section of the transformer of a brushless synchro according to Claim 7, including the steps of pre-winding the transformer stator winding, assembling the U-shaped laminations around the winding in a mould with the limbs of the U directed radially inwards, and supporting them therein with the said angulary spaced relationship, and introducing a thermosetting epoxy resin into the mould and curing the resin to secure the laminations together and to the winding to form a rigid structure.

12. A method according to any one of Claims 9 to 11 wherein the wall of the mould or a separate jig within the mould is provided with locating recesses which accommodate parts of the laminations so as to support the laminations with the said angularly spaced relationship.

13. A method according to Claim 12 wherein the parts of the laminations which fit into the locating recesses are provided by lugs on the laminations, which lugs are removed from the completed structure following its removal from the mould.

14. A brushless synchro substantially as shown in and as hereinbefore described with reference to Figure 1 of the accompanying drawing or the modifications thereof substantially as shown in and as hereinbefore described with reference to Figures 2 or 3.

For the Applicants,

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1347484 COMPLETE SPECIFICATION
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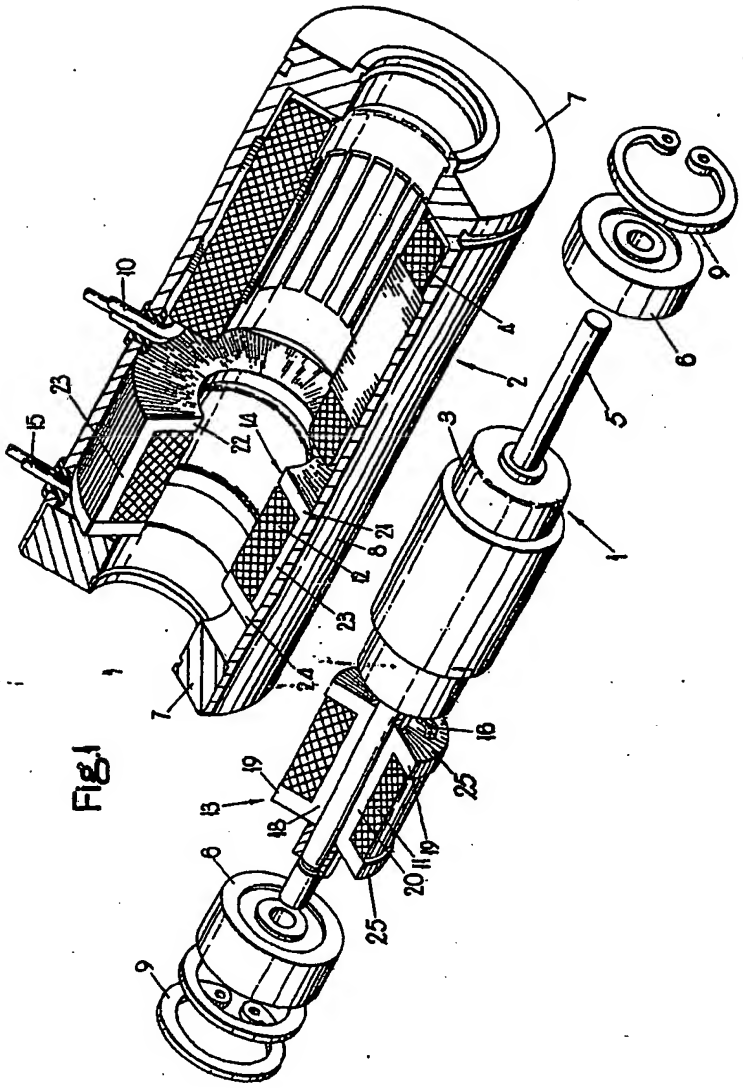

Fig.1

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1347484 COMPLETE SPECIFICATION
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Sheet 2

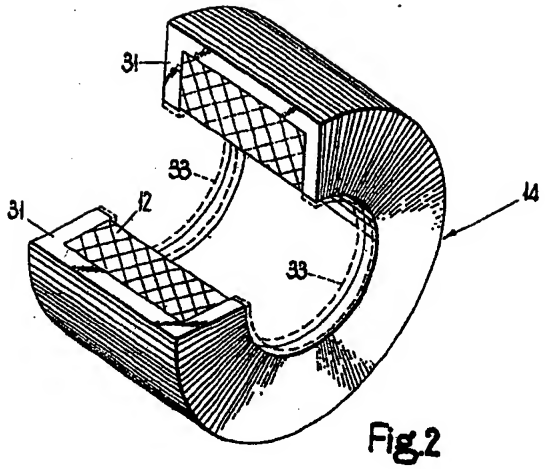

Fig.2

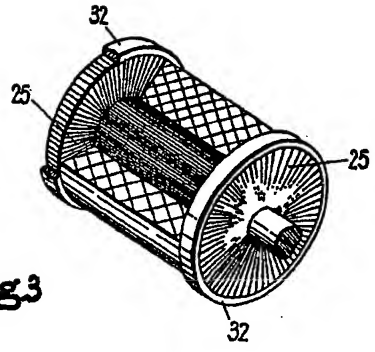

Fig.3